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Making Artificial Snow for Laboratory Use

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Ice spheres with a mean radius of 100 micrometers can be produced using a sonic nebulizer at 20 kHz. A collection of these spheres makes a very uniform type of artificial snow that is useful for laboratory experiments.

Keywords: snow, ice

Many studies have shown anomalous surface effects on ice because of quasi-liquid surface layer (Fletcher 1970, Adamson 1982, Sommerfeld and Lamb 1986). A quantitative understanding of ice surface chemistry has not yet been developed. Studies to develop such an understanding depend on a source of ice having a well-defined and high ratio of surface area to volume similar to that of natural snow. However, natural snow starts as very complex, vapor-grown shapes. In a snowpack, snow particles tend to fuse together and recrystallize, changing the shape (Sommerfeld and LaChapelle 1970). Problems associated with these complex shapes contribute to the large scatter in the data from studies on natural snow. Thus, studies that are dependent on having a well-defined surface area are better achieved by utilizing artificial snow.

We have designed a system for producing a consistent type of artificial snow that has given reproducible results when tested with Darcy permeability measurements of specific surface area (Sommerfeld, in prep.[2]). Data are reliable and can be replicated to a degree of accuracy much higher than those produced by previous studies. The utilization of artificial snow will aid in acquiring accurate ice surface chemistry data.

Equipment

The water source in this system was a Barnstead Nanopure II[3] ion exchange system that provided 18 megohm water. The Styrofoam chamber prevented stray air currents from disturbing the stream of droplets. A Dewar flask filled with liquid nitrogen was located in the bottom of the chamber to catch and freeze the water droplets (fig. 1).

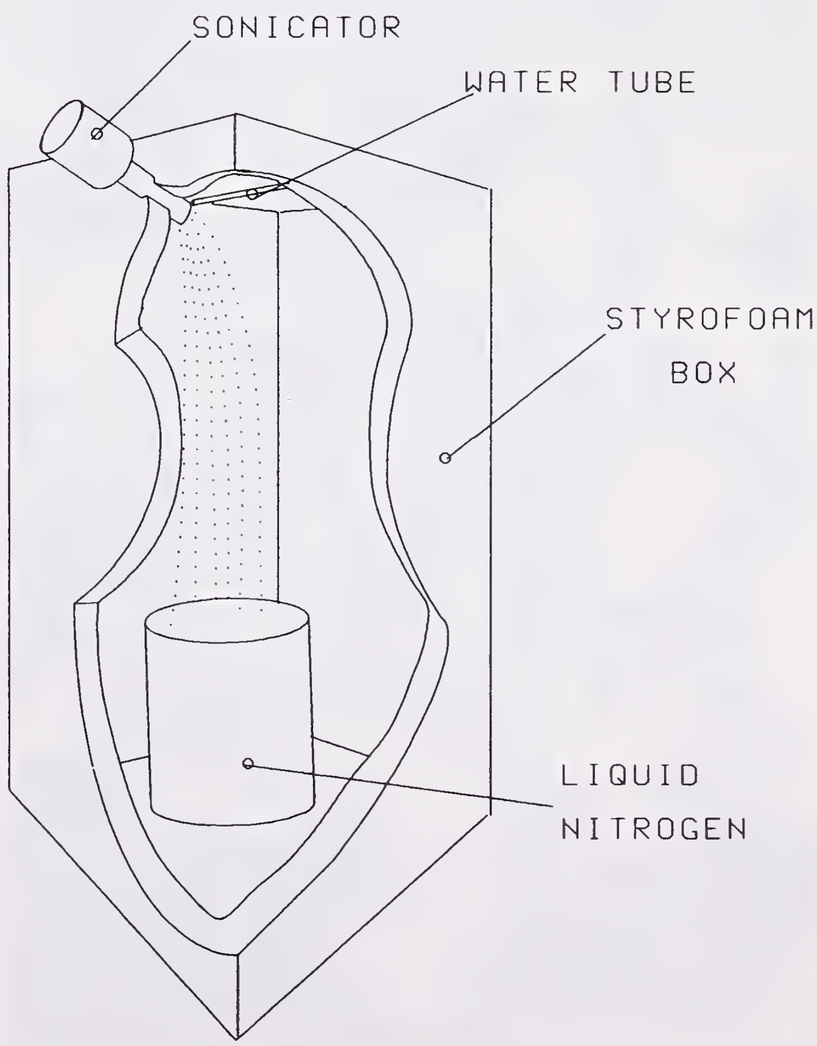

Figure 1.—Schematic diagram of the snow apparatus made of 3-inch Styrofoam (front view).

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[2] *Sommerfeld, R. A. in prep. The Darcy permeability of high density artificial snow.*

[3] *The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.*

Procedure

Ice Sphere Production

High-purity water, flowing at 30 to 50 cm^3/min, was introduced through a plastic tube attached to a glass syringe that was used to direct the flow of water to the tip of a sonic nebulizer. The sonic nebulizer used was the ENI Power Systems model EGR800B power generator with a maximum output of 300 watts. The generator, which drives a model 102 convertor from the Branson Sonic Power Company,[3] has an adjustable output frequency in the range 0 to 105 kHz. Impedance matching was accomplished with a 100-ohm, 500-watt resistor in series with the convertor, resulting in an adequate power ratio. The size of the droplets is a function of the frequency at which the (Branson 20 kHz) horn is driven, and the 20 kHz frequency used produced droplets with a mean radius of about 100 μm (fig. 2).

This droplet size was chosen because Perla's (1978) calculations indicated the change of a radius of curvature from 10-μm ice spheres to 100-μm ice spheres takes of the order of days while the change from 100-micron to 1-mm spheres takes of the order of months. A slow rate of change is necessary so that the change in specific surface area of the sample is undetectable or at least negligible during experiments that could last several hours. After the droplets were formed, they fell into a wide-mouth Dewar flask that had been filled with liquid nitrogen to freeze them instantly. The quick freezing is necessary to prevent clumps or clusters of ice from fusing together. After a sufficient quantity of snow was formed, it was sifted through a 200-micron screen into liquid nitrogen to remove any coarser particles formed when stray water-drops fell into the flask.

Figure 2.—Illustration of snow beads taken before packing of column.

Column Preparation

Glass columns, 25.4 mm inside diameter by 250 mm long, were prepared by freezing a film of ice on the interior. The ice film insured adhesion of the artificial snow to the walls, preventing any wall-flow around the sample. The bottom of the tube was covered with a fine wire screen to keep the snow from falling out during packing. Dry ice was packed around the column to keep the snow from melting or sintering during this process. Snow was poured into the column with the aid of a funnel. At temperatures below –40°C, the snow acts similarly to loose sand. A rod was used to stir air and evaporating liquid nitrogen out of the column during packing and to slightly compress the sample; this is critical to obtaining homogeneous columns without large void spaces. The top of the column was closed with fine screen, and the column was placed in a plastic bag and stored in a freezer. Freezer storage at about –10°C for several days resulted in sintering of the snow particles. Sintering and aging eliminate small radii of curvature, particularly the very sharp areas of negative curvature where the particles touch. Thus, the major part of the change in surface area caused by sintering was completed before experiments were run.

Measurements

Darcy Measurements

Darcy theory is stated:

$$Q = K\ DP/DL$$

where Q is the volume flow rate per cross section, K is the Darcy constant, and DP is the pressure drop along the length DL of the tube. K is a function of $(1/\ A_s)^2$, where A_s is the specific surface area. The Darcy constant is a very sensitive measure of the change of specific surface area if the other conditions are constant, as in our experiments.

For our study, 22 measurements of Darcy permeability were performed on one tube and 59 on another (table 1). Measurements on each column took about 2 hours and were separated by about 3 hours. The overall precision of the Darcy constant measurements was less than 0.3%. No change in the Darcy constant was observed during either set of measurements, and the Darcy constant was similar for the two columns (table 1).

Thin Section Measurements

To directly observe the specific surface area of ice at several locations in the column, we utilized the section-plane method as described by Perla et al. (1985). The resulting specific surface areas and point-density measurements are also given in table 1.

Table 1.—Measurement results.

Column	Point density Mean	Point density SD	Specific surface mm^{-1} Mean	Specific surface mm^{-1} SD	Intrinsic permeability m^2
1	0.672	0.048	25.7	3.5	$3.29 \times 10^{-11} \pm 0.03$
2	0.598	0.065	27.2	1.2	$3.48 \times 10^{-11} \pm 0.03$

Conclusions

The consistency of the section-plane measurements of point density and specific surface area among the column sections was very good, indicating that each column was very homogeneous. Measurements of Darcy permeability, over a period of about 2 hours for each column, showed no measurable change in the specific surface area in this time period. Measurements on the second column were begun about 3 hours after the first, providing additional evidence that changes in specific surface area were slow in the time scale of the experiments, in agreement with Perla's (1978) results.

The consistency between the measurements on the two different columns indicated that columns can be produced that are more than consistent enough for experimentation. Thus, the two criteria, homogeneity of individual columns and insignificant change of specific surface area for experiments of a few hours' duration, can be met if the columns are prepared carefully according to the instructions given above. These columns will allow the careful measurements of Darcy permeability over a range of conditions. Such measurements combined with surface section measurements of the specific surface areas should provide an accurate set of baseline measurements to be used in evaluating experiments on natural snow. They will also be useful in performing accurate measurements of the adsorption of gasses on the surface of ice.

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